METNET ATMOSPHERIC SCIENCE NETWORK FOR MARS.

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Introduction

A new kind of planetary exploration vehicle for Mars is being developed. The MetNet mission to Mars is based on a new semi-hard landing vehicle called Mars Meteorological Lander (MML). The scope of the MetNet Mission is eventually to deploy several tens of MMLs on the Martian surface using inflateable descent system structures. The MML will have a versatile science payload focused on the atmospheric science of Mars. Detailed characterisation of the Martian circulation patterns, boundary layer phenomena, and climatological cycles requires simultaneous in-situ meteorological measurements from networks of stations at the Martian surface.

The MetNet payload includes devices for surface atmospheric and soil observations, and a panoramic imager. Also the payload includes devices for measuring the atmospheric pressure and temperature profiles and a descent imager taking nested pictures from the landing area during the descent.

The MetNet prototype has been developed and the critical subsystems have been qualified for Martian environmental and functional conditions. Presently a suborbital test launch is under preparation to test the descent systems of the MetNet. The first mission step in the MetNet Mission is to have a MetNet Precursor Mission with a few MMLs deployed to Mars.

The MetNet -type of mission is what the Martian atmospheric science currently needs. Time-resolved *in situ* Martian meteorological measurements acquired by the Viking (Hess et al., 1977; Chamberlain et al., 1976) and Mars Pathfinder landers and remote sensing observations by the Mariner 9, Viking, Mars Global Surveyor, Mars Odyssey and the Mars Express orbiters have provided the basis for our current understanding of the behavior of weather and climate on Mars. However, the available amount of data is still scarce and a wealth of additional *in situ* observations are needed on varying types of Martian orography, terrain and altitude spanning all latitudes and longitudes to address microscale and mesoscale atmospheric phenomena. Detailed characterization of the Martian atmospheric circulation patterns and climatological cycles requires simultaneous *in situ* atmospheric observations by a network of stations at the Martian surface (Haberle and Catling, 1996; Barnes et al., 1993; **?**; Harri et al., 1999). The MetNet mission will provide the logical next mission tool in the field of Martian atmospheric science.

Figure 1: Two MetNet vehicles being separated from the spacecraft. Separation takes place before reaching the Martian orbit to save fuel mass (Harri et al., 2003).

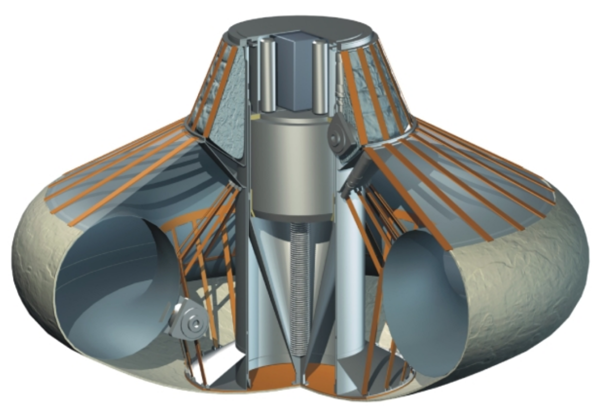

Figure 2: MetNet vehicle in the entry configuration. The inflatable heat shield with the diameter of 1.0 m has been coated with an ablative material for thermal protection (Harri et al., 2003).

1 MetNet Mars Mission

The unfortunate cancellation of the NetLander mission underlined the need of atmospheric *in situ* observations at Mars. While the NetLander and Mars-96 missions targeted a wide range of geophysical science disciplines, there remained a need for a mission that would focus more directly the atmospheric science objectives. To that end the MetNet mission concept was developed.

We initiated a new type of atmospheric science mission for Mars. The MetNet Mars Mission is to deploy a network to the Martian surface consisting of some tens of atmospheric science observation posts. This type of a network will enable simultaneous *in situ* observations all over the Martian surface. The network is designed to operate for several Martian years, which facilitates detailed characterization of the Martian circulation patterns, boundary layer phenomena, and climatological cycles. The payload and landing vehicle development work benefits significantly from the experience gained during Mars-96, NetLander, Mars Polar Lander and Mars Express missions. We developed concepts of designing highly integrated packages of space science instruments and system devices during the Mars-96 Mission, and thus enhanced our experience in the course of the subsequent missions. The currently ongoing MetNet mission is being developed in collaboration between the Finnish Meteorological Institute (FMI), the Babakin Space Center (BSC) and the Russian Space Research Institute (IKI) as described by Harri et al. (2003).

The mission endeavors to develop an extensive atmospheric science payload onboard a landing vehicle that requires fewer pyrotechnical commands and less mass in the entry, descent and landing system (EDLS) than the traditional parachute-based EDLS (Harri et al., 2003, 2004a). The EDLS is depicted in Figures 1, **??** and 2. Additionally, the vehicle and payload are designed to survive hard landing on the Martian surface. The mass optimization target is approached from both the EDLS and the payload design. To survive the hard impact the payload will be densely integrated without easy-to-use disassembling capability, which will give mass savings. Optimizing the total mass to payload mass ratio requires that the payload design and manufacturing processes must be performed in a unified fashion, essentially by one design team.

The novel idea behind the MetNet landing vehicles is to use state-of-the-art inflatable entry and descent systems instead of rigid heat shields and parachutes that earlier semi-hard planetary landing devices have used. This way the overall reliability is increased due to diminished number of pyrotechnical devices, the ratio of the payload mass to the overall mass is optimized, and more mass and volume resources are spared for the science payload. This semi-hard landing vehicle using inflatable descent system structures is called the Mars Meteorological Lander (MML).

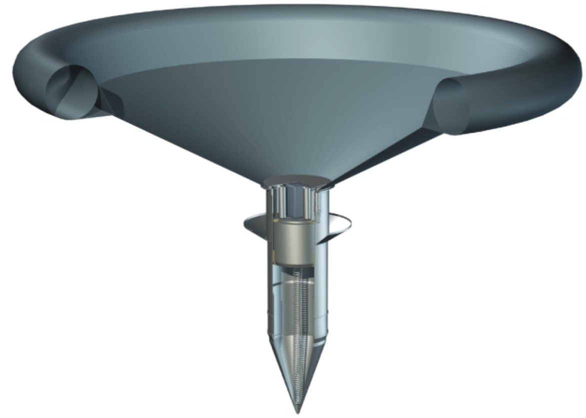

Figure 3: MetNet landing module in the configuration prior to the landing impact on the Martian surface. The diameter of the torus-shaped main decelerating structure is 200 cm, and the height of the penetrating body in front of the module is 87 cm (Harri et al., 2003).

The scientific payload of the MetNet Mission encompasses separate instrument packages for the atmospheric entry and descent phase and for the surface operation phase. For the descent phase an imager, accelerometers and devices for free flow pressure and temperature observations are envisaged. At the Martian surface the MML will take panoramic pictures, and perform measurements of pressure, temperature, humidity, wind direction and speed, as well as atmospheric optical depth.

The scope of the MetNet Mission is eventually to generate the observation network over the course of several years. This is possible due to the fact that the MML lifetime is designed to be a few years. Hence the network can be established and expanded by sending MMLs to Mars using launches in successive launch windows. This strategy also mitigates the risk of losing the network by one single launch failure. The first real mission step is to have a MetNet Precursor Mission with a few MMLs deployed to Mars. Partnership discussions are being conducted with other space organizations.

The MetNet development work has been going on since autumn 2001. Initially, five different entry, descent and landing system scenarios were investigated. One of them was the traditional parachute-based system, the rest of the analyzed concepts were based on using inflatable structures to decelerate the vehicle descending into the Martian atmosphere. Figure 3 presents the MetNet vehicle in the form it assumes just prior to impacting on the Martian surface. The chosen concept for the MML entry, descent and landing system is composed of the following systems and units:

- Surface module that finally stays at the Martian surface;

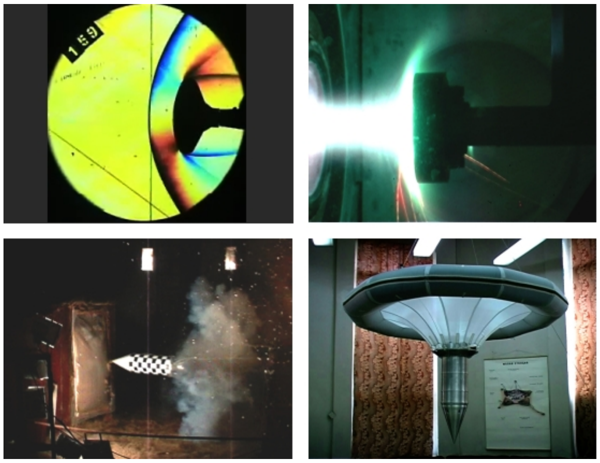

Figure 4: The MetNet entry, descent and landing system has been qualified for Martian conditions. This figure depicts (from upper left) some aerodynamic tests of the entry vehicle, hot plasma blasting of the heat shield material, shock testing of the landing probe and the manufactured full scale prototype.

- Rigid section of front aerodynamic shield;
- Inflatable heat protection section;
- Main inflatable decelerating device (IBU) with gas generator and load-bearing elements;
- Additional IBU with gas generator;
- Forebody with shock-absorbing system.

As a result of detailed studies in 2001 - 2002 the chosen descent system scenario was found to be feasible for Martian exploration. The capabilities of the system parts were examined by numerical simulations. In 2002 - 2004 the new descent system prototype was manufactured and key parts were exposed to environmental tests to qualify the design for the conditions the system will encounter during the entry into the Martian atmosphere. The tests were successful and demonstrated the applicability of the developed MetNet concept for Mars.

At present the MetNet prototype has been developed and the critical subsystems have successfully passed the proper environmental and functional tests. Currently a suborbital test launch by a Russian SS-19 missile is under preparation to test the descent systems. This test will take place in 2005: the test prototype will be launched into space and made re-enter the atmosphere of the Earth with the same velocity and entry angle with which the probe will eventually enter the Martian atmosphere. A photo of the MetNet prototype with FMI MetNet team is depicted in Figure 5.

The individual MetNet vehicle (MML) deployment to the Martian surface takes place in the following fashion (Harri et al., 2003):

- Spacecraft is targeted and the MML is separated when still on the approaching path to Mars; this is more economical than jettisoning the MML from Martian orbit.
- Autonomous flight to Mars (from a few days up to some weeks).
- Entry into the Martian atmosphere. The inflatable heat shield is deployed at the Mach number (M) of approximately 29. At this phase the vehicle speed is reduced from supersonic speed to subsonic speed.
- The additional inflatable deceleration structure is deployed when the speed is reduced to $M \cong 0.8$. By means of this device the speed of the landing vehicle is reduced to about 70 m/s by the time the vehicle reaches the Martian surface.
- Impact onto the Martian surface (maximal deceleration 500g over the time of 50 ms) and penetration into the soil thus obtaining a proper operating attitude.
- Systems start-up and checkout.
- Scientific investigations program.

The overall reliability of the developed MML concept using a two-cascade approach was found to be 1.7 times more reliable than the traditional parachute -based landing concept. The mass gain seems to be only of the order of 10% when compared to the parachute -based landing system.

Figure 5: Prototype of the MetNet entry vehicle has been fabricated and all the key descent systems have been exposed to the entry conditions. This figure shows the MetNet prototype with FMI MetNet team from left: P. Makkonen, H. Lappalainen, B. Fagerström, and A.-M. Harri.

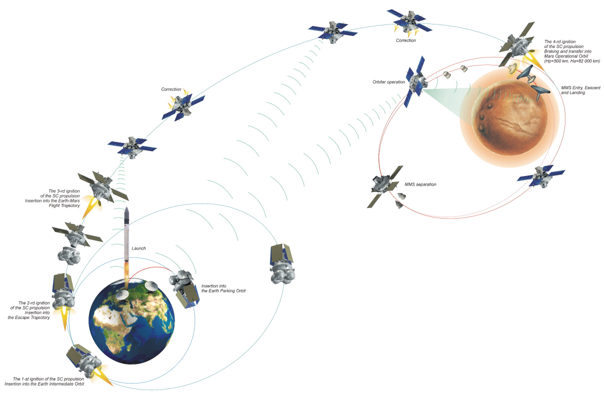

Figure 6: One possible mission scenario for the MetNet Mars Precursor Mission utilizing a missile launch

Optimal locations of the MetNet observation posts at the Martian surface depend on the total amount of the network elements as discussed in Chapter **??**. If the network consists of only a few observation posts, it is worthwhile to either create a small local network or to place the posts on different types of terrain and latitudes. This would encompass differences in altitude, latitude and type of surface. In all cases we should place observation posts also on the locations, where observations were previously performed by the Viking Landers and the Mars Pathfinder. This would enable us to compare the current atmosphere at those sites to the atmospheric conditions prevailing earlier. This would be especially interesting at the Viking Lander sites, where observation records of several Martian years are available. Repeating atmospheric observations at those sites now could even facilitate climatological investigations.

Access below the Martian surface provides the MetNet mission with some unique opportunities for studying the Martian soil. We hope to look for the presence of subsurface water by means of a water ice detection device mounted at the front part of the penetrating vehicle body. Also, we envisage studying the thermal conductivity of the soil by measuring the rate at which the probes cool down after impact. To accomplish this, temperature sensors have to be mounted on the forebody structure.

If the number of observation posts is of the order of 20 or more we can already create a global network (Haberle and Catling, 1996). If the number of observation posts would significantly exceed 20 it is possible to create a global network including a section were the observation post density is remarkably higher than elsewhere. This dense section would be placed on an area of particular interest from the atmospheric science point of view, *e.g.* in the vicinity of expanding and retreating polar caps, Hellas region or Valles Marineris.

The MetNet mission will be an excellent tool for enhancing our understanding of the Martian atmosphere. Having a network of *in situ* instrument payloads all over the Martian surface operating simultaneously is what the scientific community has dreamed of for decades. This can now be realized using the MetNet concept.

The MetNet mission is currently taking its shape and the mission development organization is being put together. The first mission step is to have a MetNet Mars Precursor Mission (MMPM) with a few MMLs deployed to Mars as depicted in Figure 6. One possibility is to launch the MMPM with a missile equipped with an extra upper stage and a specific cruise phase carrier.

A viable and cost-effective option is to launch the MetNet Precursor Mission from a submarine, as illustrated in Figure 7. A similar launch approach will be utilized in testing the MetNet entry and descent system by a sub-orbital test launch. The MetNet Mars Precursor Mission is preliminarily slated for launch in 2009 or 2011 (Harri et al., 2004b).

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Figure 7: A viable and cost-effective option is to launch the MetNet Precursor Mission from a submarine. A similar launch approach will be utilized in testing the MetNet entry and descent system by a sub-orbital test launch.

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